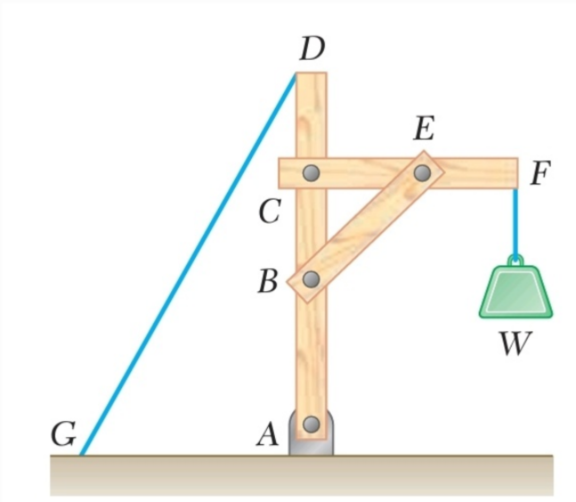
Frames → What is it ?

An load-bearing structure composed of several members (or RBs) connected using pin joints such that ATLEAST one member is NOT a two-force member.

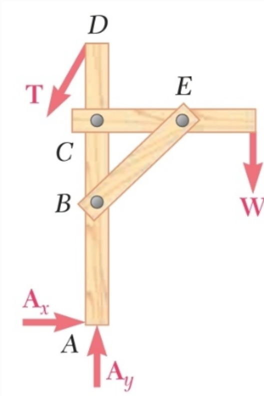
In other words, frames must have at least one multi-force member, i.e. member acted upon by three or more forces

* The forces are generally not directed along the members on which they act

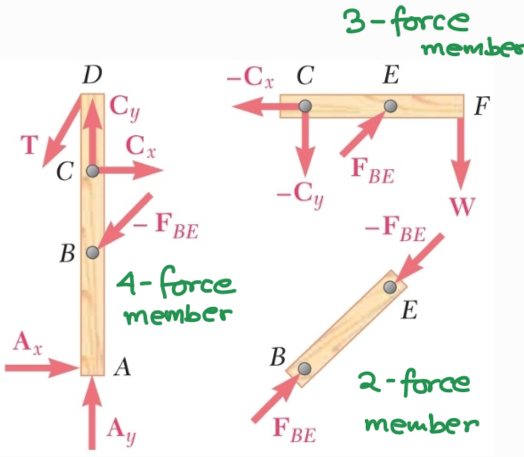
E.g. crane



- All pin joints
- Support A is also pinned
- GD is a cable



FBD of crane



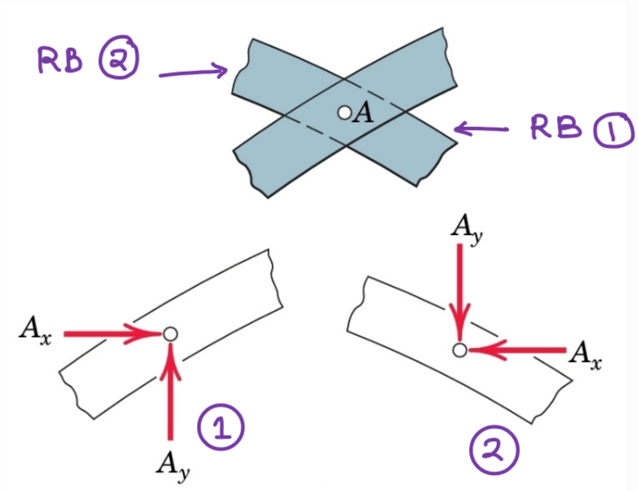
FBD of individual members

In contrast to frames, a truss is an assembly of members where all individual members act as two-force members

Analysis of frames

As frames are interconnected rigid bodies which include multiforce (more than two-force) members, the forces acting on each member are found by isolating the member with FBD and applying the equations of static equilibrium.

↳ Newton's 3rd law of action and reaction must be carefully observed when representing the forces of interaction on the separate FBDs.

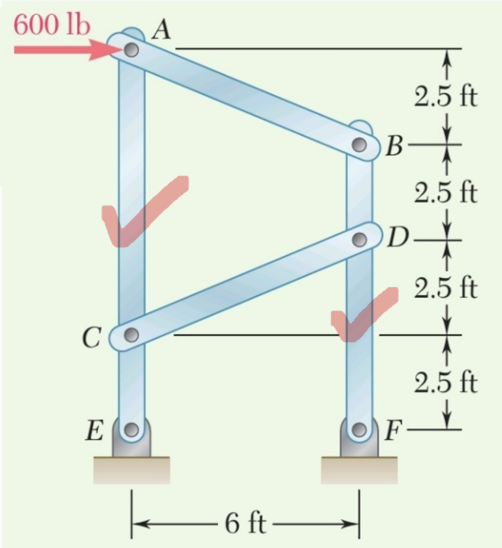


Next, we will write down the general guidelines for analyzing a frame structure, useful for solving problems involving frames containing one or more multi-force members

Let's take an example to understand how to analyze frames.

Sample Problem 6.6

A 600-lb horizontal force is applied to pin *A* of the frame shown. Determine the forces acting on the two vertical members of the frame.



Is it a frame? (Atleast one member must be a multiforce member)

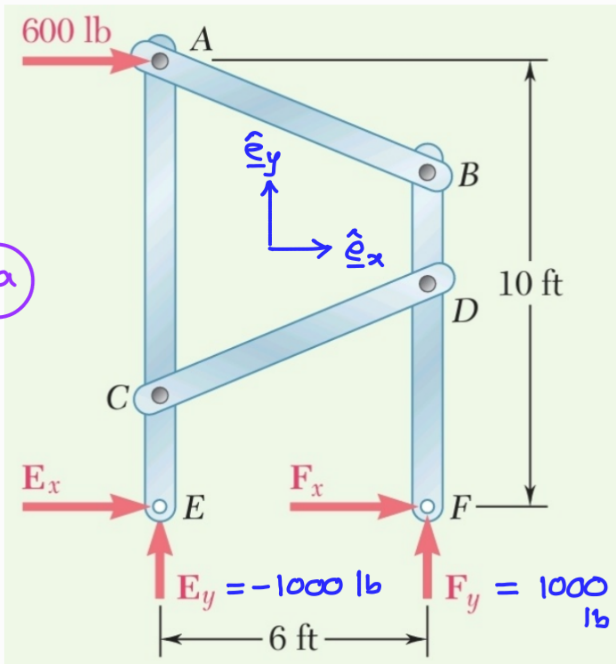
Strategy:

① Begin with FBD of entire frame to try and determine all the reactions

(sometimes the # of reaction forces maybe greater than three equations and we cannot determine them all right away)

② Then you analyze the members separately and return in order to determine the remaining reactions

Choose the entire frame for drawing the FBD and use equations of static equilibrium



$\overset{+}{\rightarrow} \sum F_x = 0 \Rightarrow E_x + F_x + 600 = 0$ — (1a)

$+\uparrow \sum F_y = 0 \Rightarrow E_y + F_y = 0$ — (1b)

$+\circlearrowleft \sum M_E = 0 \Rightarrow -(600)(10) + F_y(6) = 0$

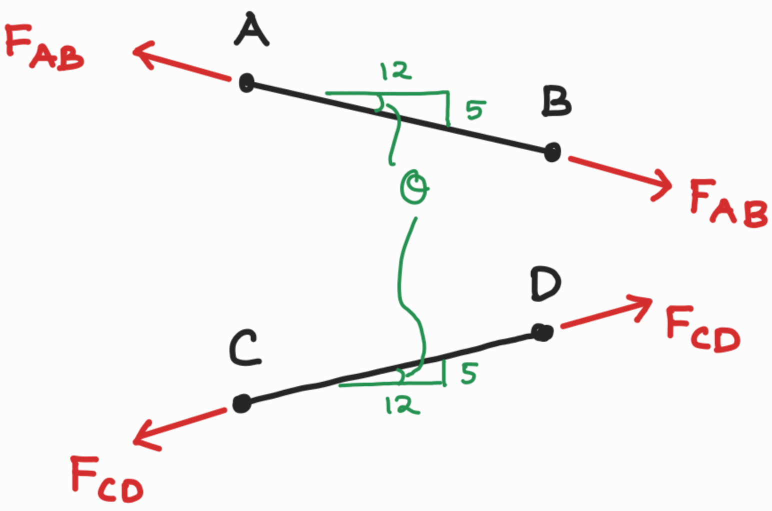
moment abt pt E

$\Rightarrow F_y = 1000$ lb — (1c)

E_x and F_x are still undetermined!

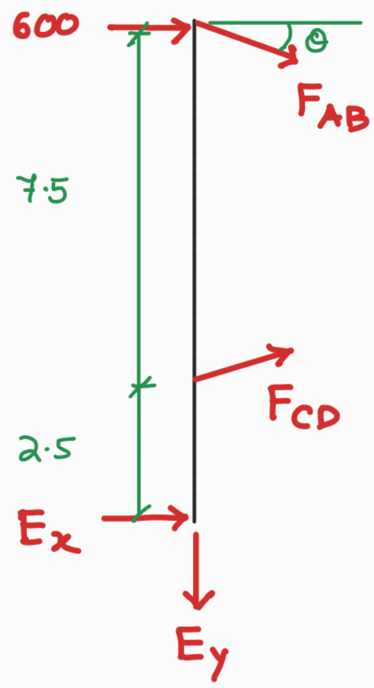
We will now consider the FBDs of the members.

Members AB and CD are two-force members



$$\tan\theta = \frac{5}{12}$$

Member ACE



$$\overset{+}{\rightarrow} \sum F_x = 0$$

$$\Rightarrow \quad 600 + E_x + F_{AB}\overset{12/13}{\cos\theta} + F_{CD}\overset{12/13}{\cos\theta} = 0$$

$$\Rightarrow \quad F_{AB} + F_{CD} = -\frac{13}{12}(600 + E_x) \quad \text{— 2a}$$

$$+\uparrow \sum F_y = 0$$

$$\Rightarrow \quad -F_{AB}\sin\theta + F_{CD}\sin\theta - \overset{-1000}{E_y} = 0$$

$$\Rightarrow \quad -F_{AB} + F_{CD} = \frac{13}{5}(-1000) \quad \text{— 2b}$$

$\overset{+}{\circlearrowleft} \Sigma M_E = 0 \Rightarrow -(600)(10) - (F_{AB}\cos\theta)(10) - (F_{CD}\cos\theta)(2.5) = 0$

$$\Rightarrow \quad 10\,F_{AB} + 2.5\,F_{CD} = -\frac{13}{12}(600)(10) \quad \text{— 2c}$$

Using 2b and 2c

$$\left.\begin{aligned} F_{AB} &= -1040\ \text{lb} \\ F_{CD} &= 1560\ \text{lb} \end{aligned}\right\} \text{Use in 2a} \Rightarrow E_x = 1080\ \text{lb}$$

sense of F_{AB} assumed
was inaccurate, therefore it came out with a -ve sign

Now that E_x is determined, use 1a to obtain F_x

$$F_x = 1080 - 600 = 480\ \text{lb}$$

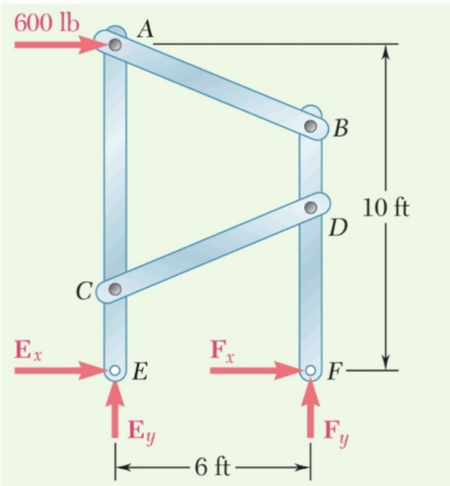
Guidelines for analyzing a frame structure

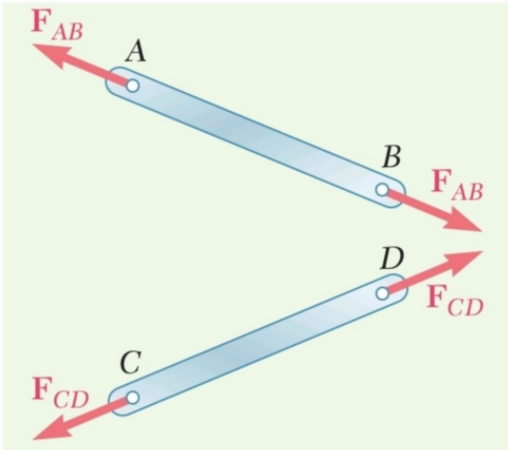
1) Draw FBD of the entire frame: To the extent possible, use this FBD to calculate the reactions at the supports

2) Dismember the frame, and draw an FBD of each member

3) First consider the two-force members

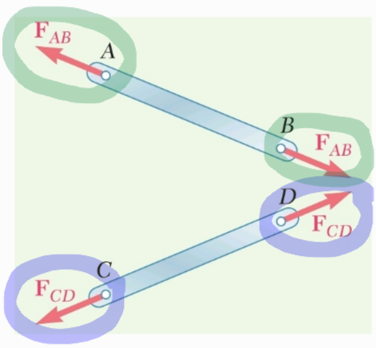
* Equal and opposite forces apply to each two-force member at the points where it is connected to another member.





* If you cannot decide whether the member is in tension or compression, assume the member is in tension.

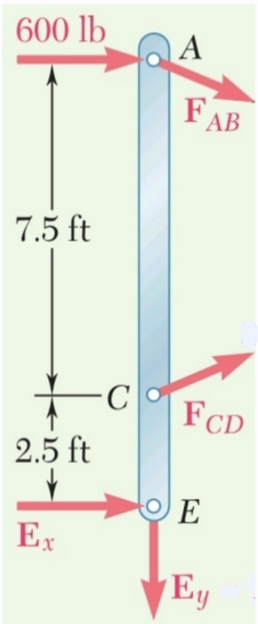
* The forces on the two-force member must have the same unknown magnitude

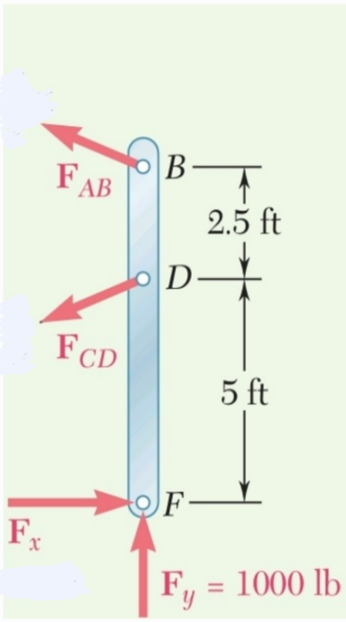


4) Next consider the multi-force members

For each of the members, show all the forces acting on the member, including applied loads, reactions, and internal forces at connections.

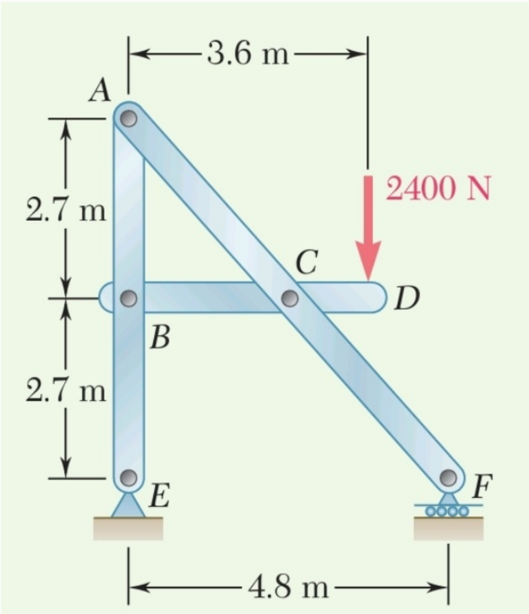
4a) Where a multi-force member is connected to a two-force member, apply a force to the multi-force member that is equal and opposite to the force drawn on the FBD of the two-force member

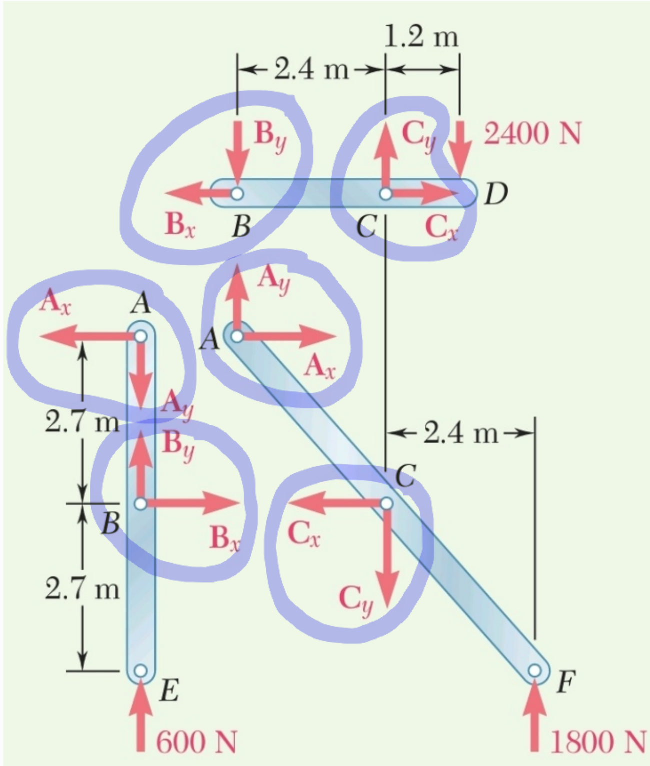




4b) Where a multi-force member is connected to another multi-force member, use horizontal and vertical components to represent the internal forces at that point. The direction and magnitudes of these forces maybe unknown, and after you choose a direction, you must apply equal & opposite force components to other multi-force member.

ex:



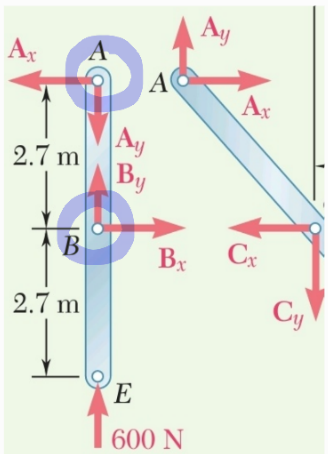


5> Determine the internal forces as well as any reactions that you have not already found

5a> FBD of each multi-force member will give you three equilibrium equations

5b> To simplify your solution, seek a way to write an equation involving a single unknown.

* If you can locate a point where all but one of the unknown force components intersect, you can sum up the moments about that point



ex. $\Sigma M_B = 0$

$\Sigma M_A = 0$

* If all unknown forces except one are parallel, you can obtain an equation in a single unknown by summing force components in a direction $\perp$ to the //el forces

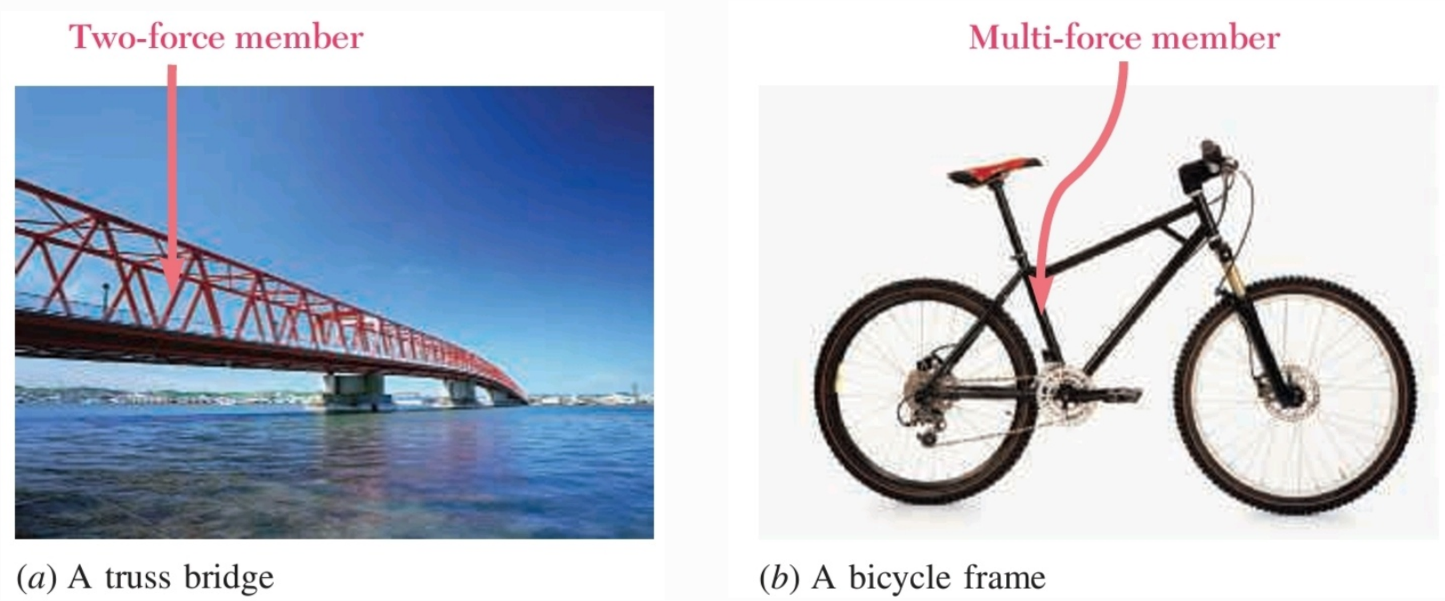
5c) Since you arbitrarily chose the direction of the unknown forces, you cannot determine whether your guess was right or wrong until the solution is complete. If the guess of direction was wrong then the sign obtained after solution will be negative, and vice versa.

Truss ⤳ Which structures can be called trusses?

* They consist of slender straight members

* The members are connected at the ends of each other by pin connections

* **ALL** members of a truss structure are **two-force members** (in contrast to frames)

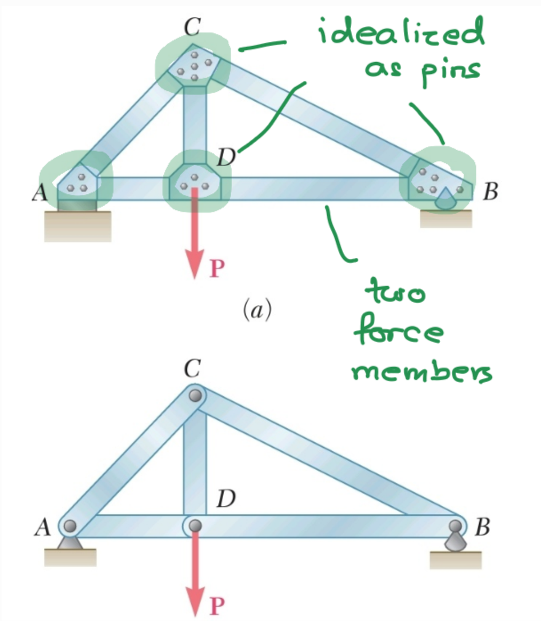


(a) A truss bridge (b) A bicycle frame

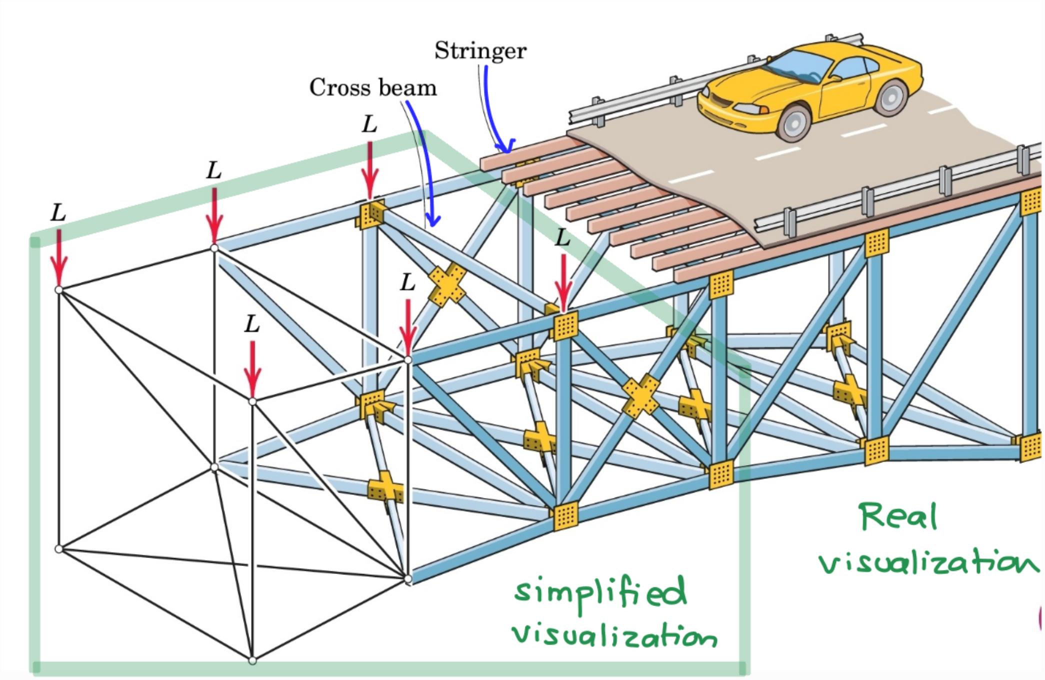
A typical truss consists of straight members connected at joints, and

→ Straight members modeled as two-force members

→ Joints modeled as pins!



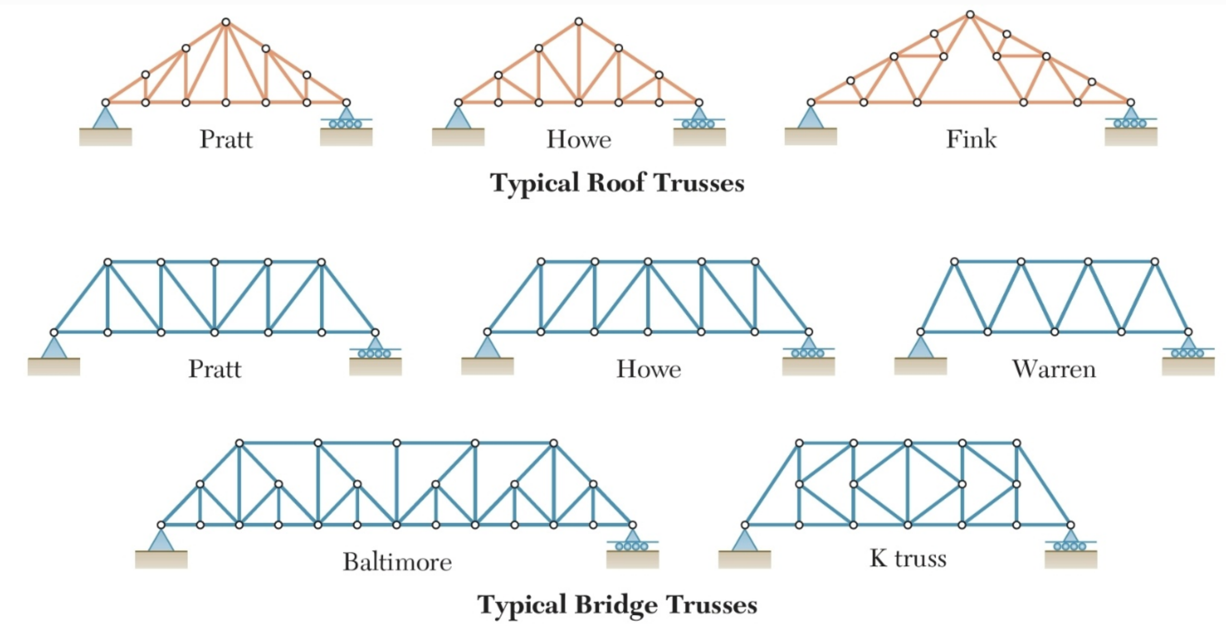
- The weight of the roadway & vehicles is transferred to the longitudinal stringers
- Stringers transfer load to cross beams
- The loads from cross-beams are transfored to the two vertical sides of the truss structure



A section of a bridge structure made of truss

Advantages: They are light-weight (compared to the loads they can withstand), and are easy to assemble

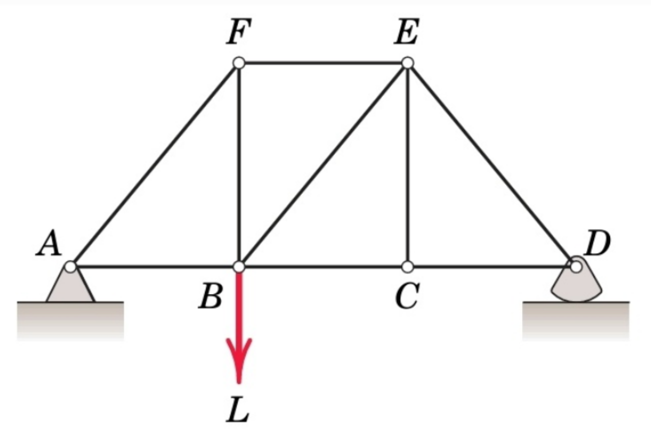
Typical trusses



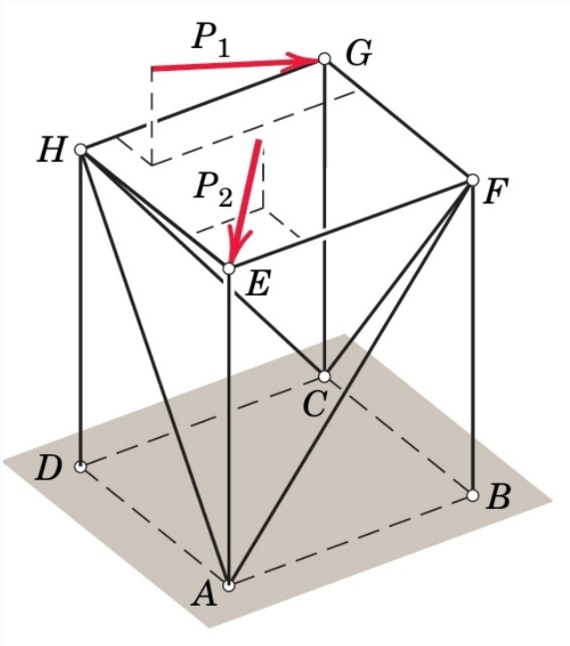
2D trusses vs 3D trusses

2D Truss: Entire truss lies in one plane and the applied forces lie in the same plane

3D Truss: (also called space truss) Non-planar truss, applied force system is non-planar



2D (plane) truss



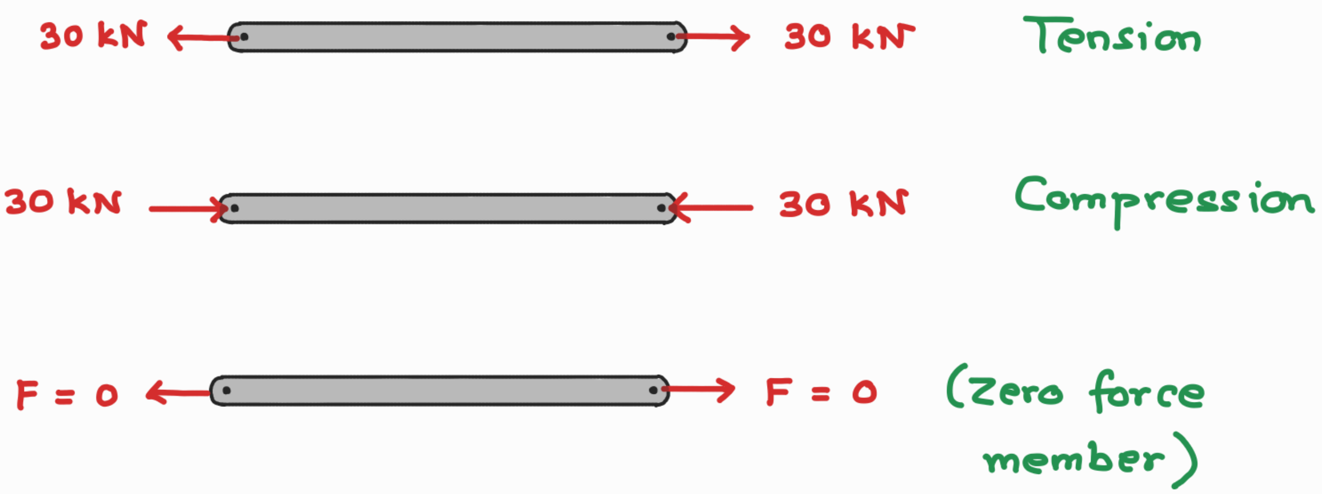
3D (space) truss

Note: All external loads are applied at pins — never anywhere between or at the ends of the members

In this course, we are going to be looking at 2D plane trusses only!

Analysis of Trusses

Since all members are straight and two-force members, they can either be in compression or tension or may turn out to be zero-force members



Analysis of trusses →
1) finding support reactions
2) finding member forces (in all of them or some of them)

There are two methods for analyzing trusses:

1) Method of joints : is for finding forces in members by using static equilibrium of each pin joint

Uses only two equilibrium equations $\Sigma F_x = 0$, $\Sigma F_y = 0$

Preferred when finding forces in ALL members

a) Method of sections: is for finding member forces by using static equilibrium of a part of truss

Takes advantage of the $\sum M_o = 0$ (moment eqn) as well

Preferred when finding forces in some specific members